Electromagnetic Calorimetry and Calorimeter Electronics

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November 9, 2015

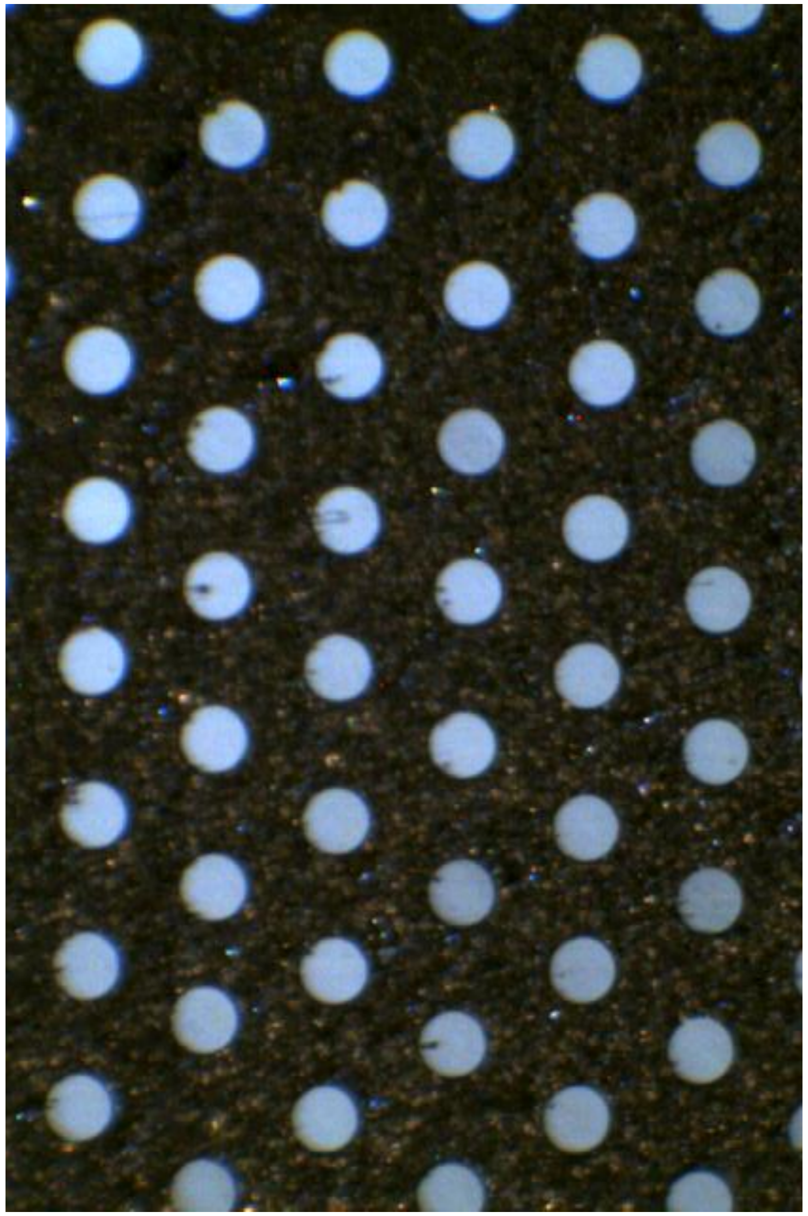
EMCal Performance Specs

- energy resolution:
  - <15%/√E, driven by γ and $e^{\pm}$ measurement
- segmentation to allow γ and $e^{\pm}$ reconstruction in central AuAu collision
- acceptance over 2π and ±1.1 in η
- together with HCal provide good jet reconstruction in central AuAu collisions
- high density to minimize radial space inside solenoid (allow room for inner HCal & tracking)
- >90x π rejection @ 70% electron eff. (=50% Υ eff.)

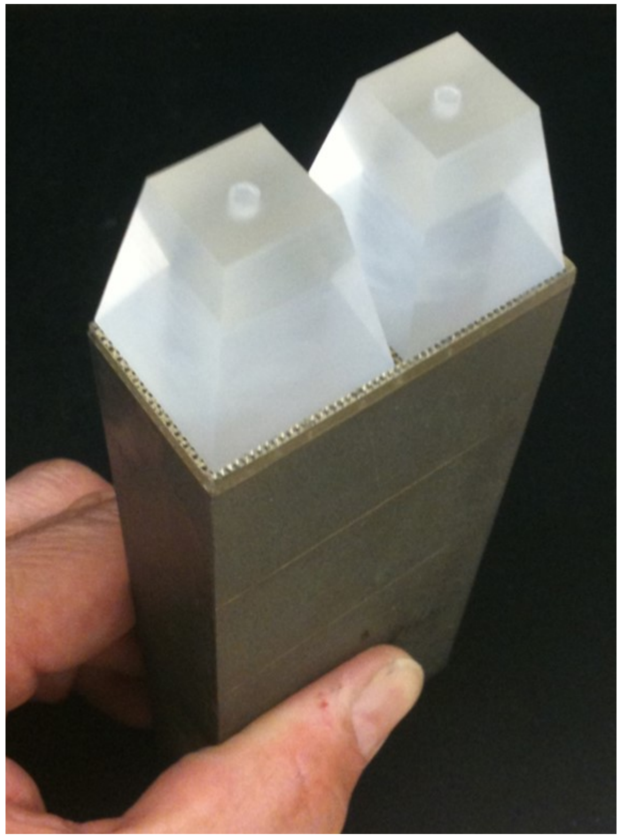
W-Fiber EMCal

- tungsten powder-epoxy embedded into matrix of scintillating fibers
  - fibers
    - diameter: 0.47mm
    - spacing: ~1mm
- density ~10g/cm3→X_0 = 7mm, R_M = 2.3cm
- can point the fibers back to collision point in 1 (or 2) dimensions to generate 1D (2D) projectivity
- tower size: ~1"x1", 0.025x0.025 in $\Delta\eta \times \Delta\phi$

tungsten-fiber cross section

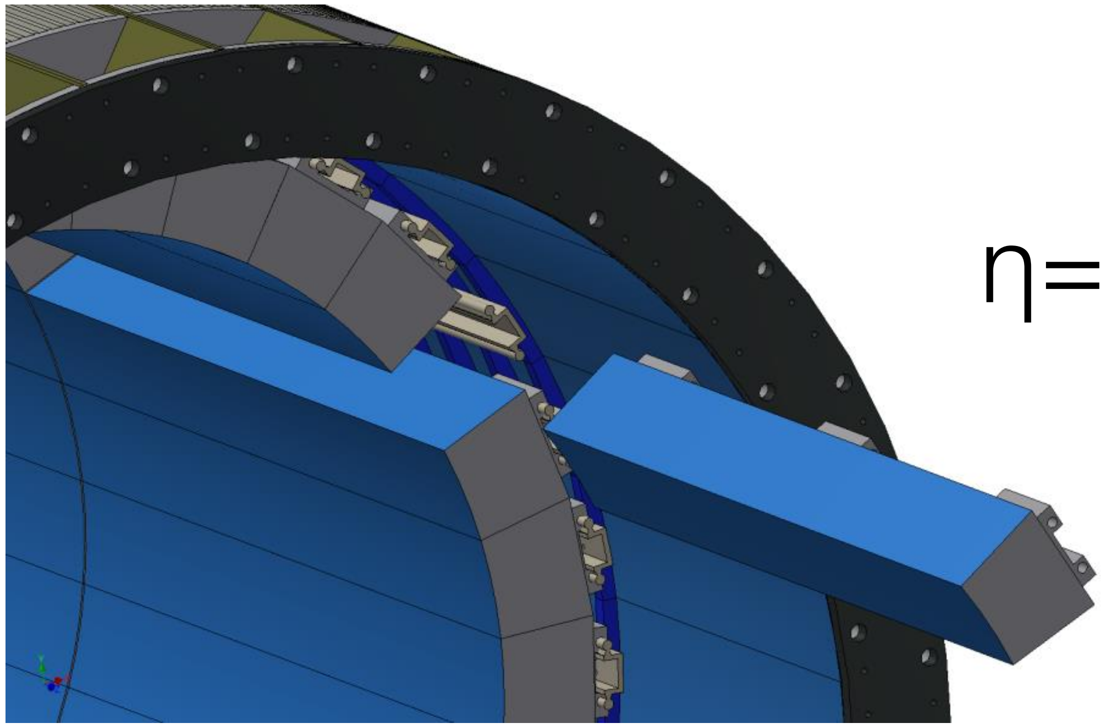


light collection & electronics

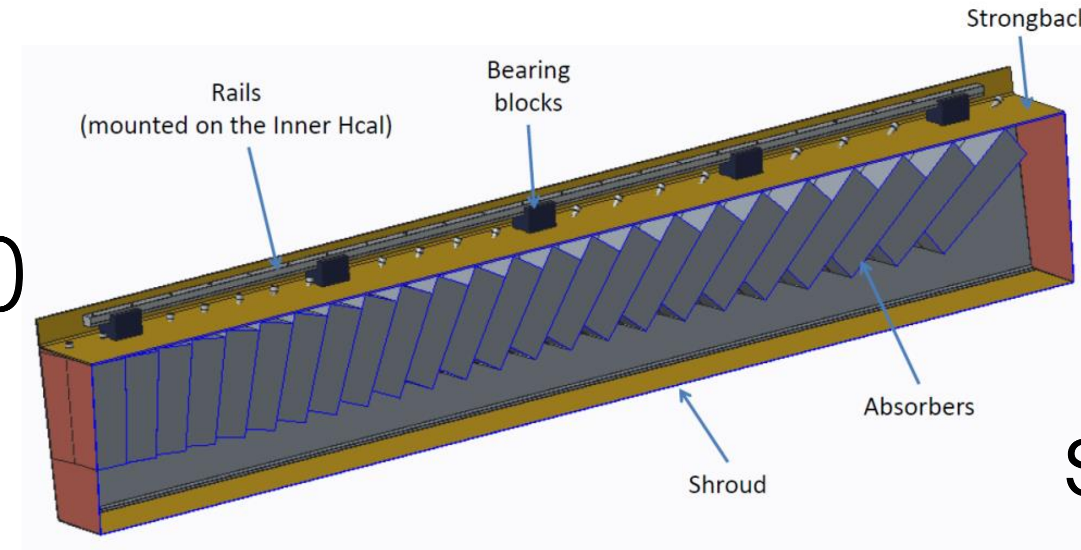


- light collection via acrylic light guides
- SiPM readout
  - 4 tiled per tower
  - ~25k towers → ~100k SiPMs
  - Hamamatsu S12572-33-015P; 15μm pixels
    - $3x3mm^2$, 40k pixels, ~10^4 dynamic range (5MeV - 50 GeV)
- read out from the inner radius of the calorimeter
- preamps with temperature compensation to provide gain stabilization of SiPM gain variation with T
- digitizer design based on those already used in PHENIX
  - 14 bit ADC, 56 MHz digitization

EMCal geometry



η=0

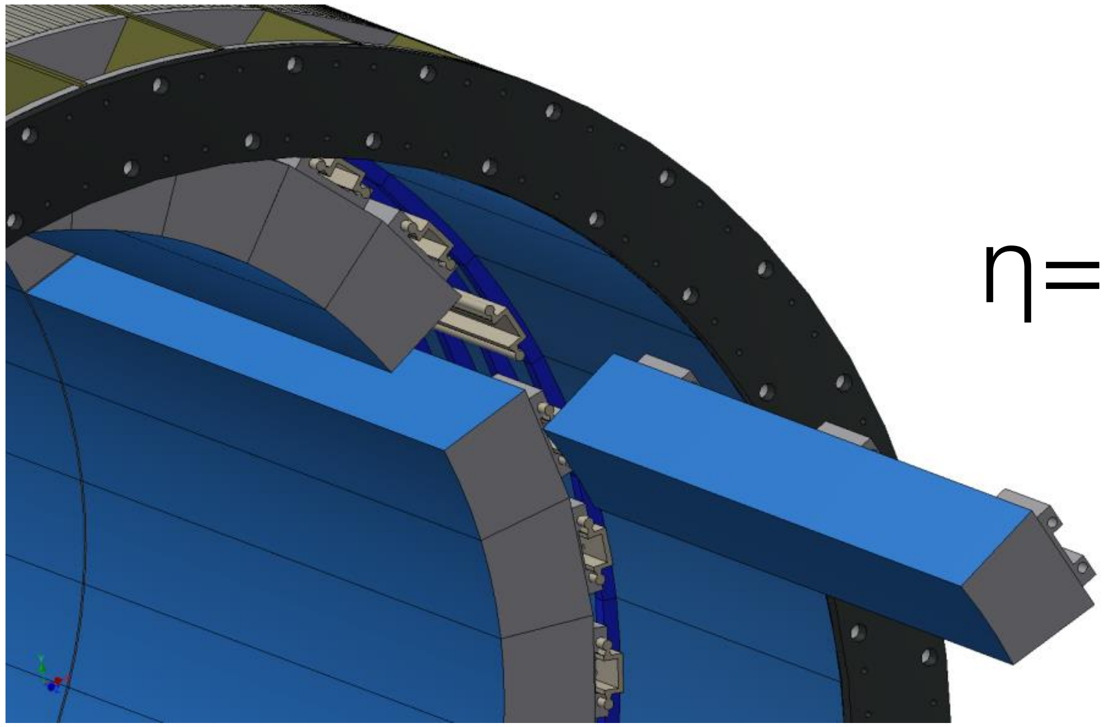


η=1

sector

		Value
Inner radius (envelope)	mm	900
Outer radius (envelope)	mm	1161
Length (envelope)	mm	$2 \times 1495 = 2990$
Number of towers in azimuth ($\Delta\phi$)		256
Number of towers in pseudorapidity ($\Delta\eta$)		$2 \times 48 = 96$
Number of electronic channels (towers)		$256 \times 96 = 24576$
Number of SiPMs per tower		4
Number of towers per module		$2 \times 8 = 16$
Number of modules per sector		24
Number of towers per sector		384
Number of sectors		$2 \times 32 = 64$
Sector weight (estimated)	kg	326
Total weight (estimated)	kg	20890
Average sampling fraction		2.3%

EMCal scope



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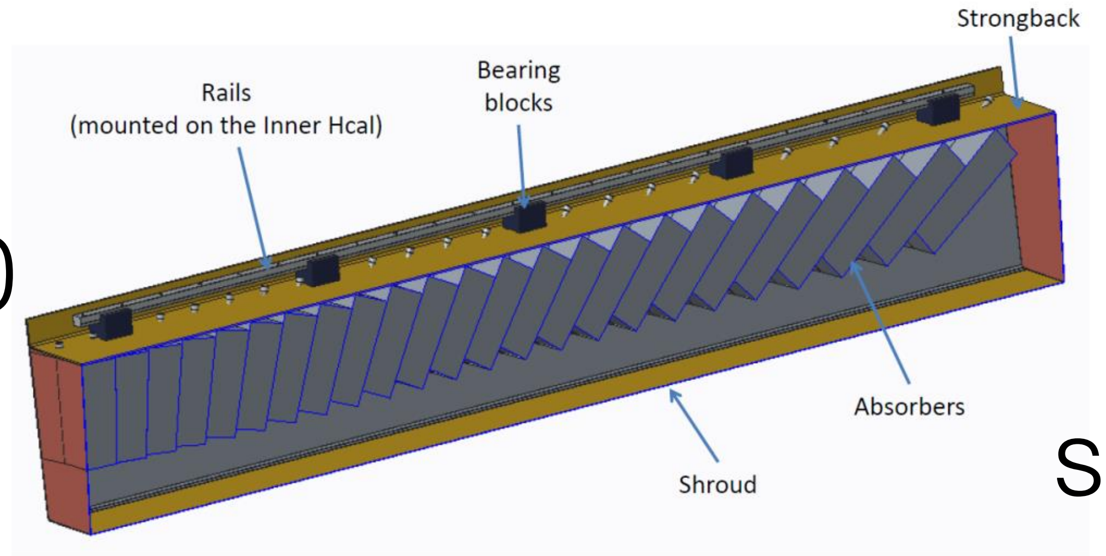
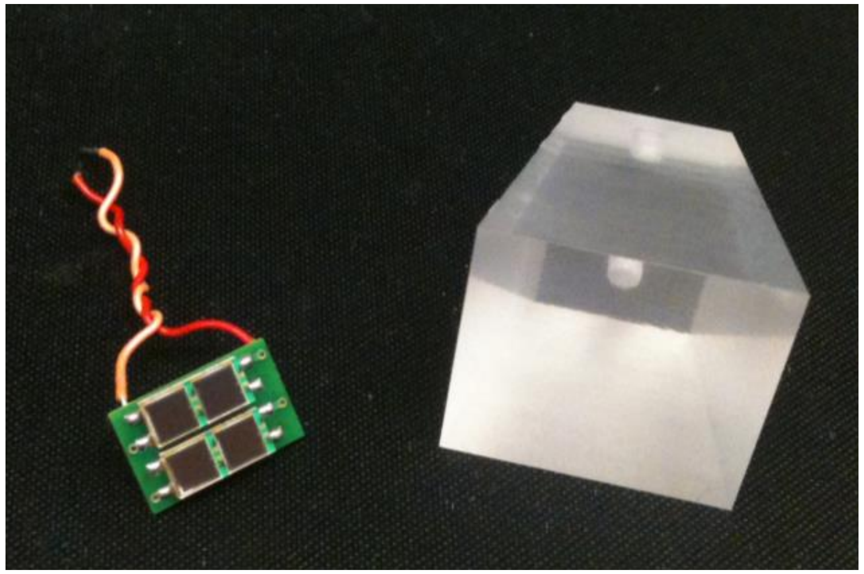


η=1

sector



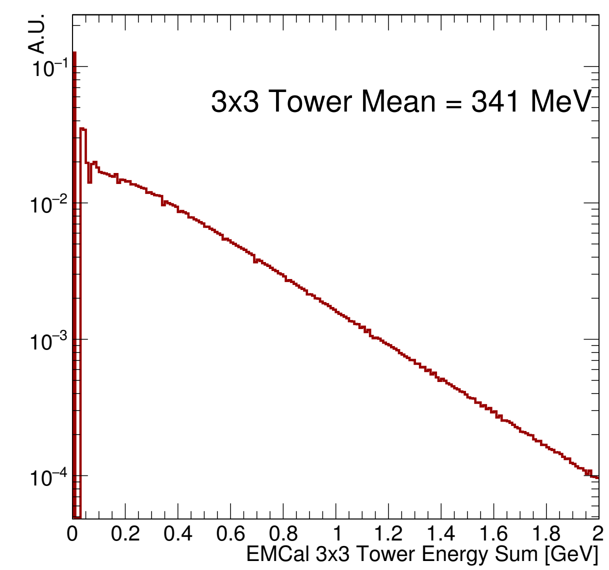
- 4 SiPM/tower: ~100k SiPM
- 3 rounds of prototyping
- module production, QA, and assembly
  - 384 towers/sector
  - 64 sectors in full detector
  - 4 SiPM/tower
  - calibration and integration into sPHENIX

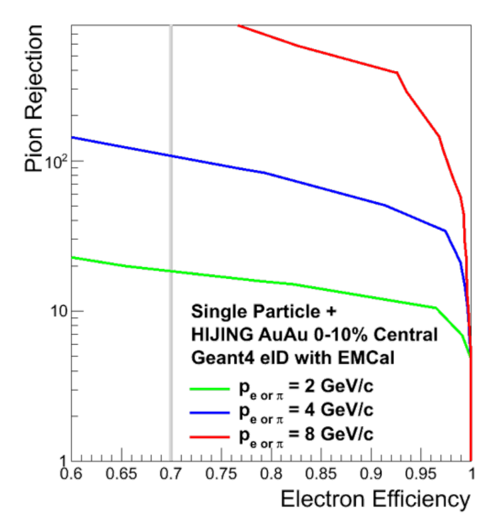
design drivers—EMCal

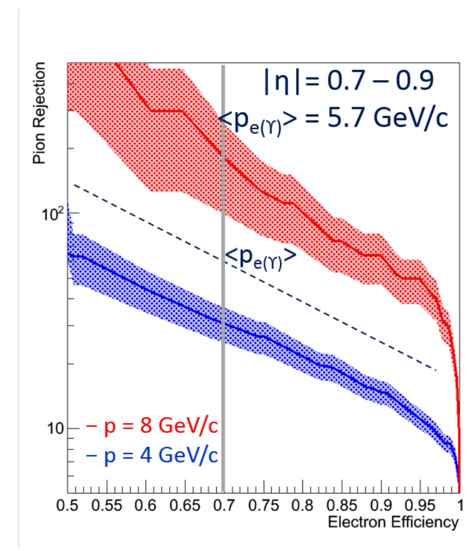
Geant4 Simulations

- segmentation and energy resolution
    - reconstruction of 5 GeV electrons in central HI environment
    - <15%/√E → EMCal will not limit electron resolution
- 2D projectivity
    - driven by electron ID requirements in central HI environment for Υ reconstruction
    - with only 1D projectivity electron-hadron separation degrades with increasing |η|
        - reduce statistics of already statistics limited measurement
    - ongoing work to increase sophistication of simulations in Geant 4 (see J. Huang's talk)

EMCal energy:
central HIJING event



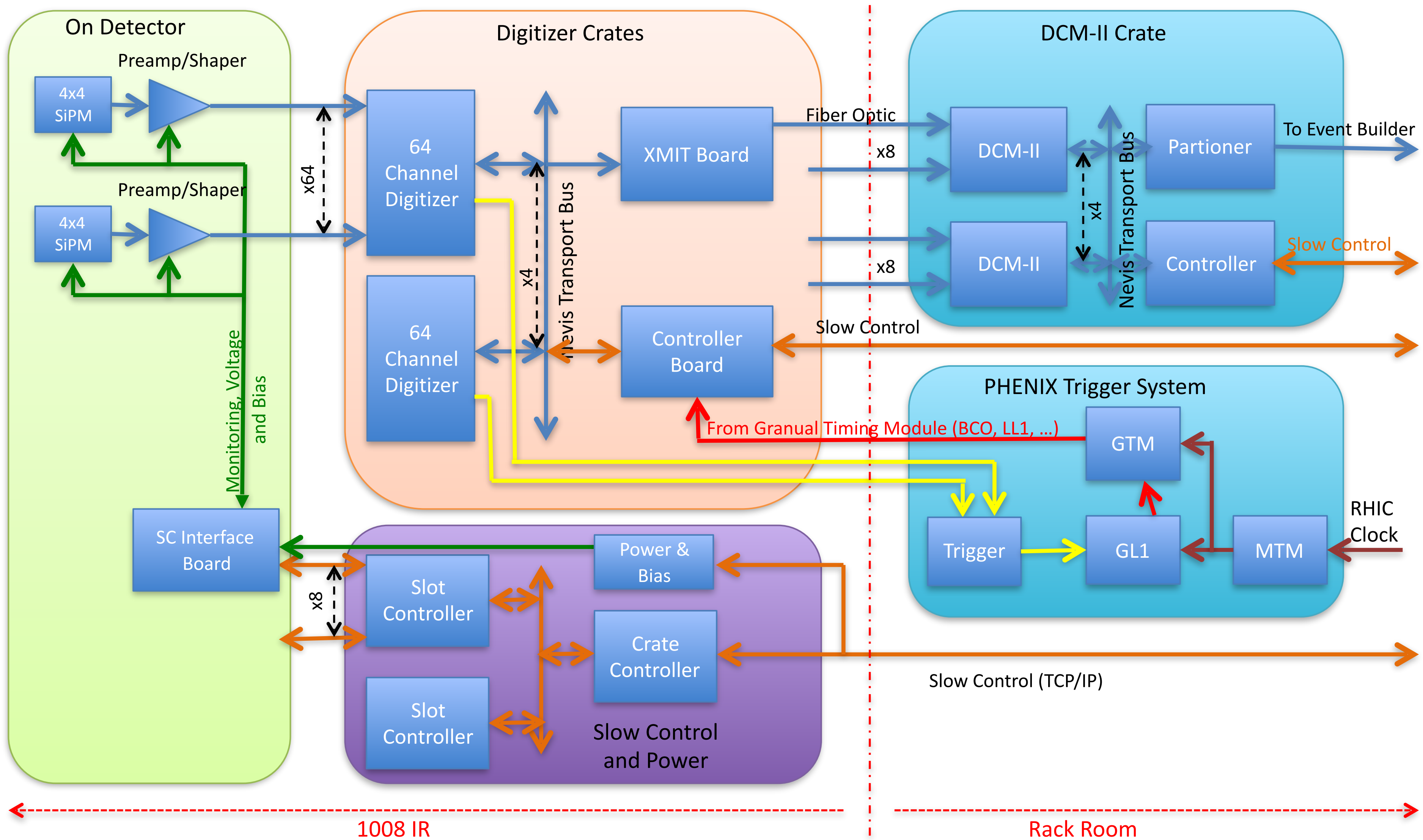




design drivers—electronics

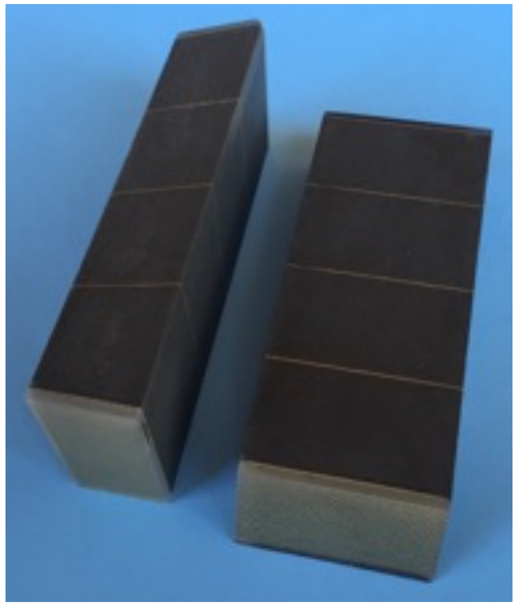
- as common as possible for EMCal and HCal
  - same sensors for both systems
  - large gain
  - work in magnetic field
  - compact
    - SiPMs
- LED monitoring/calibration system
- provide L1 trigger information from EMCal & HCal
- utilize existing PHENIX DAQ, event rate ~15kHz
  - digitizer design based on those already used in PHENIX

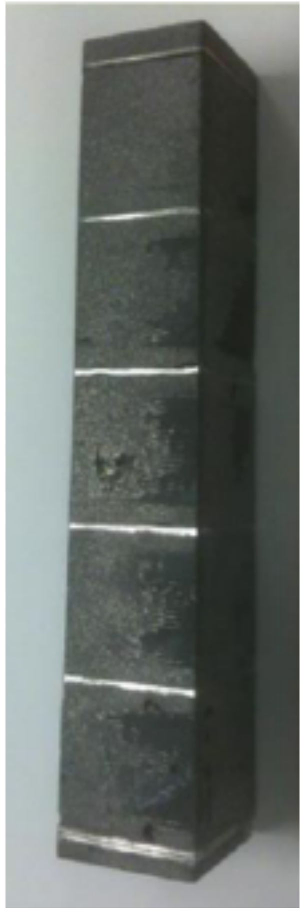
calorimeter electronics overview



schedule drivers

- R&D on 2D projective design
    - 1D projective modules (2x1 towers) have been successfully produced at UCLA, Tungsten Heavy Powder (industry), Illinois and BNL
        - production process well under control
    - 2D projective production process being developed
        - 2D projective blocks (1x1 tower) have been produced at BNL and Illinois
        - goal: 2D projective modules for v2 prototype (10/16) with a production process that will scale to full detector
        - want to make blocks bigger than 1x1 tower





cost/schedule drivers

- assembly/testing of sectors
  - large number of towers/SiPMs
  - current schedule based on university based module production assembly and testing
  - pursuing alternate industry based module production (THP), university based assembly and testing
    - understand feasibility of both module production options
      - unclear how industry module production affects cost— this will be more clear after prototyping process

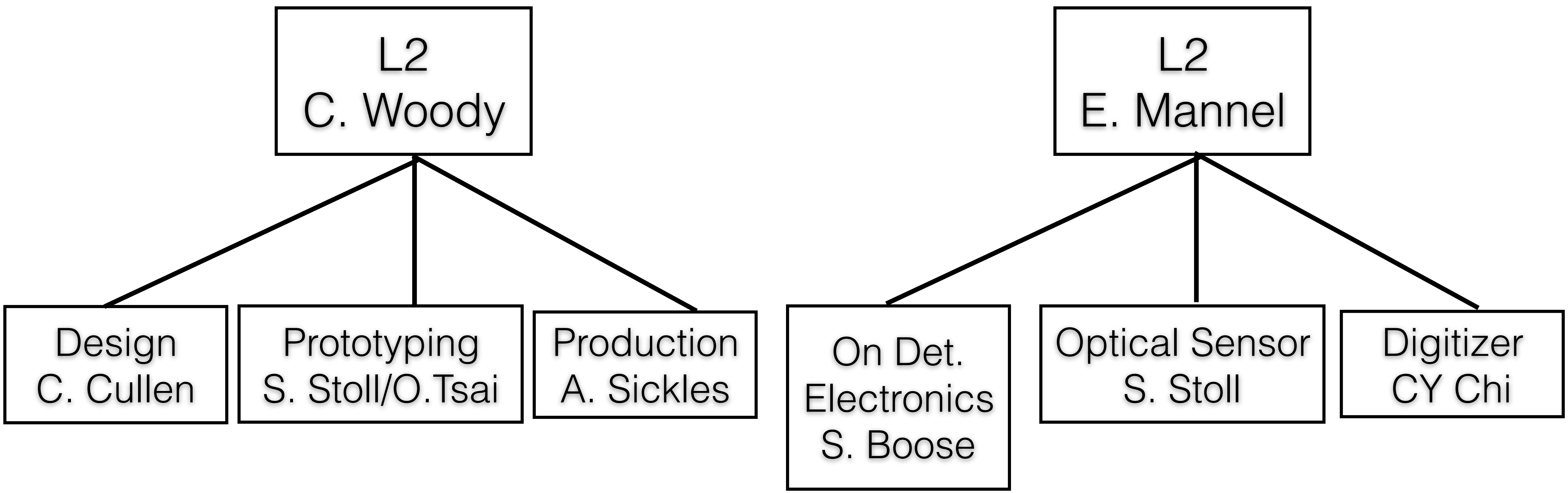
EMCal schedule summary

v1 prototype	ongoing-Apr '16
v2 prototype	Mar '16- May '17
preproduction prototypeprototype	May '17 - Jun '18
design	Apr '16 - Oct '17
module production	Jun '18 - Sep '20
supermodule assembly	Jun '18 - Sep '20
ready for detector installation	Sep '20

organization: EMCal & electronics

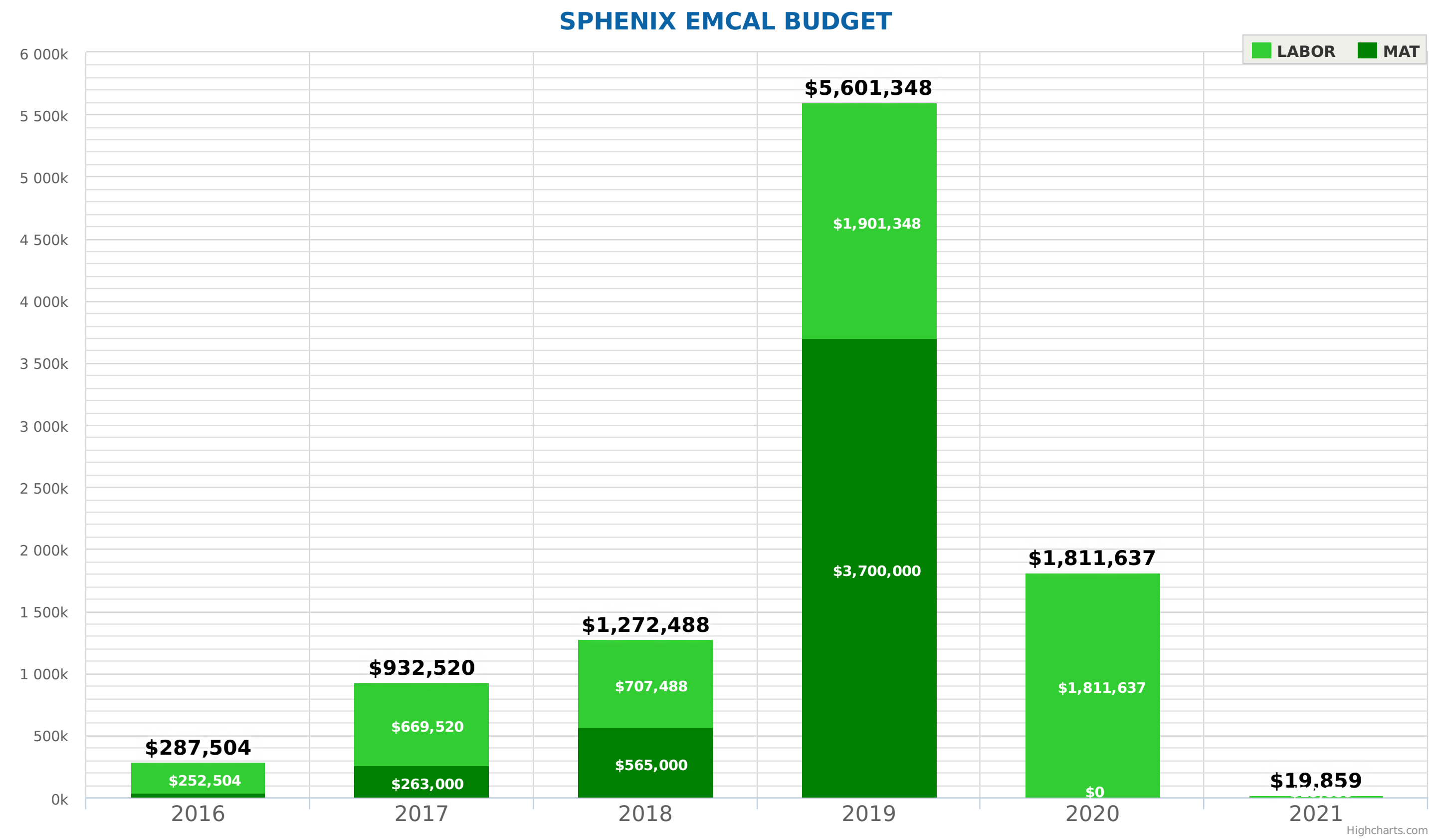
EMCal

Calorimeter Electronics

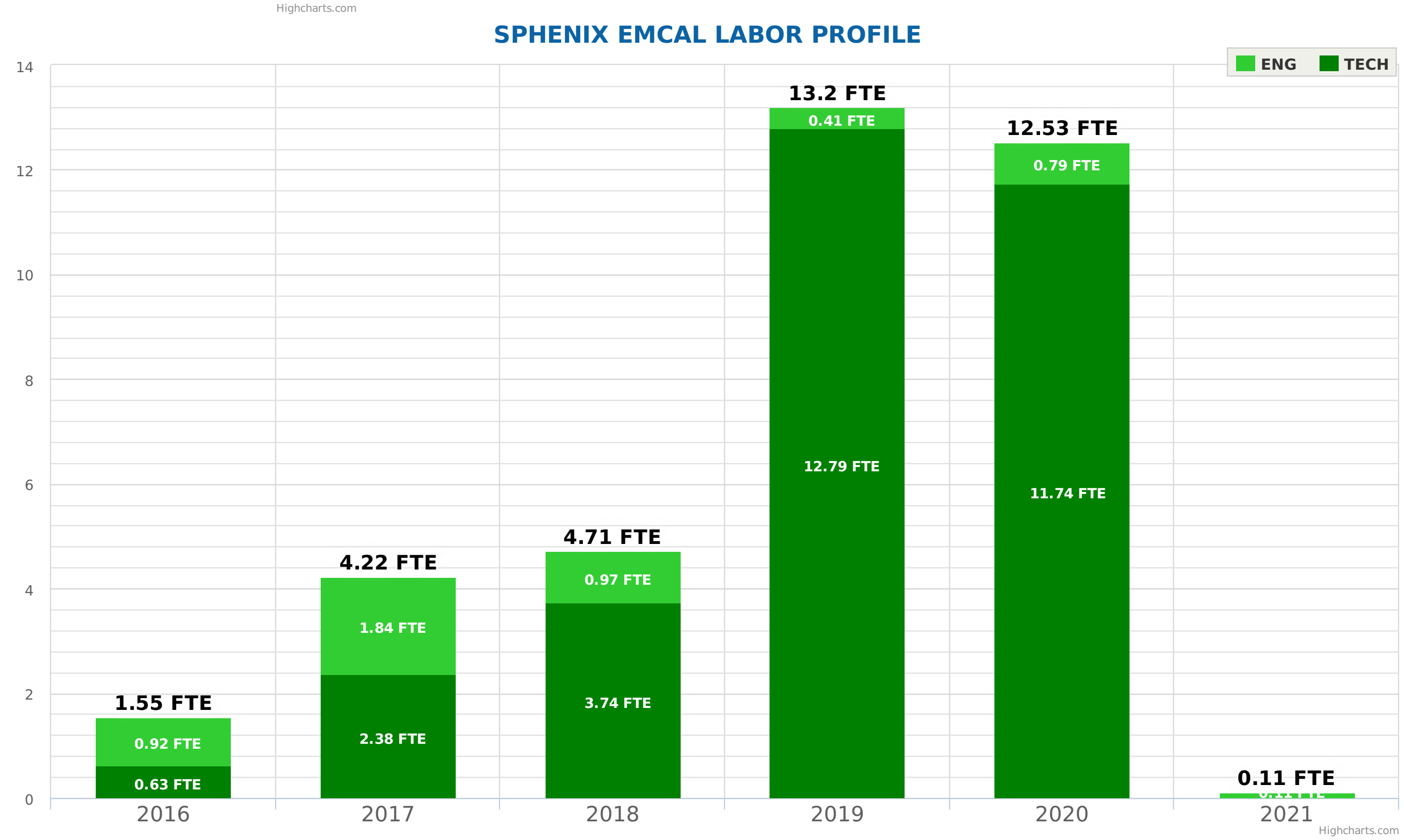


budget and labor profiles

budget



labor

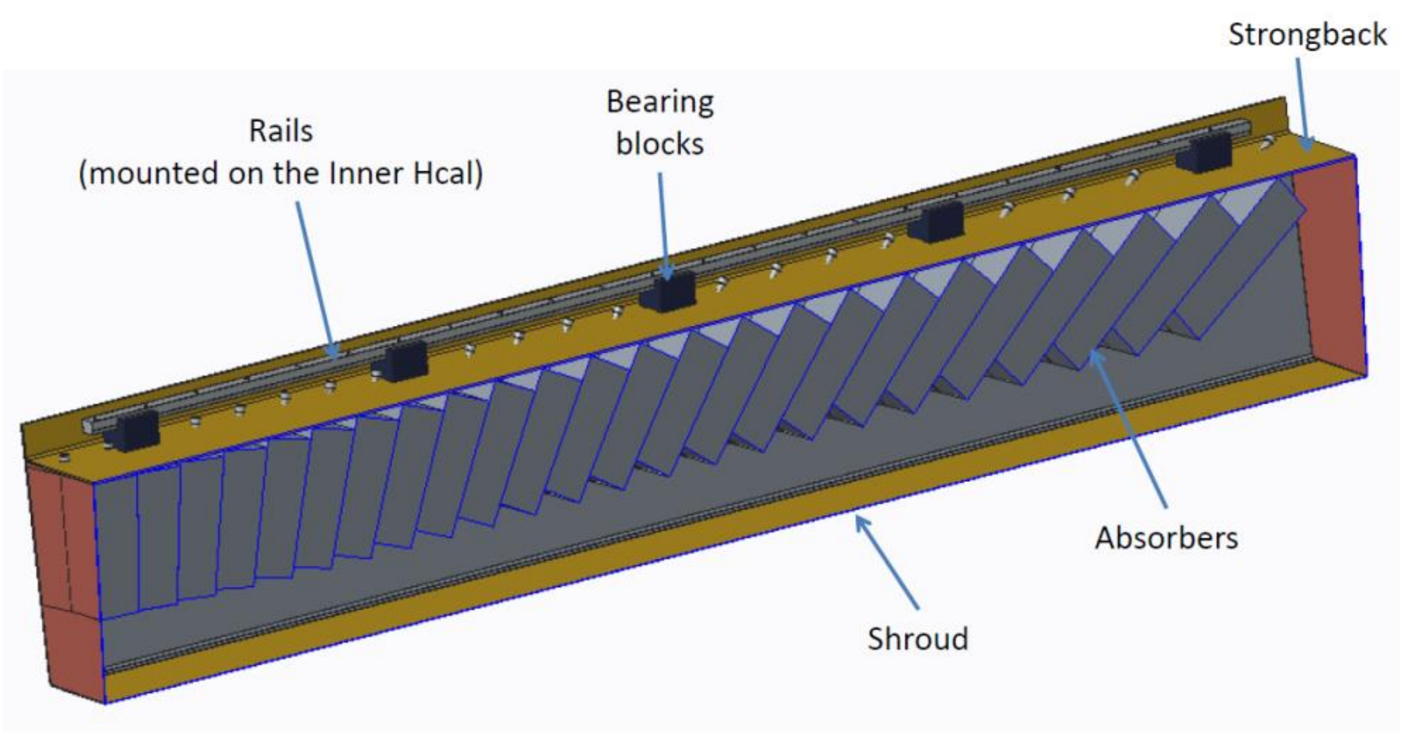


technical/project status

- 1D projective modules (2x1 towers) have been successfully produced at UCLA, Tungsten Heavy Powder (industry), Illinois and BNL
  - density: ~10g/cm3
- v1 prototyping:
  - produced both at Illinois & THP
  - to be assembled, tested at BNL
- v2 prototyping:
  - ongoing work to develop 2D projective production

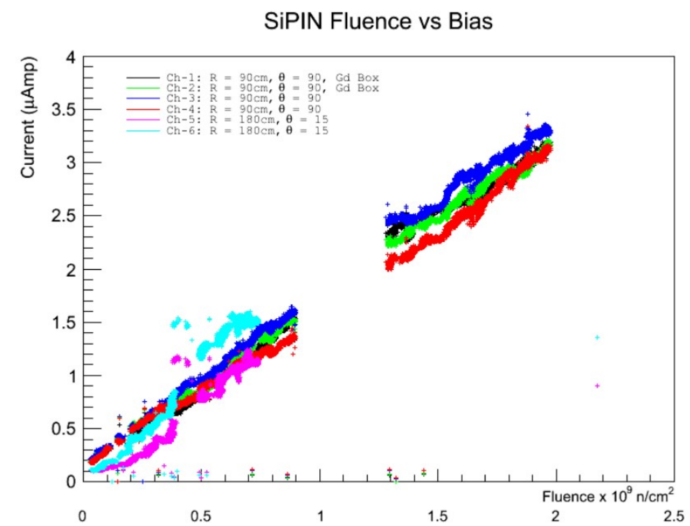
technical/project status

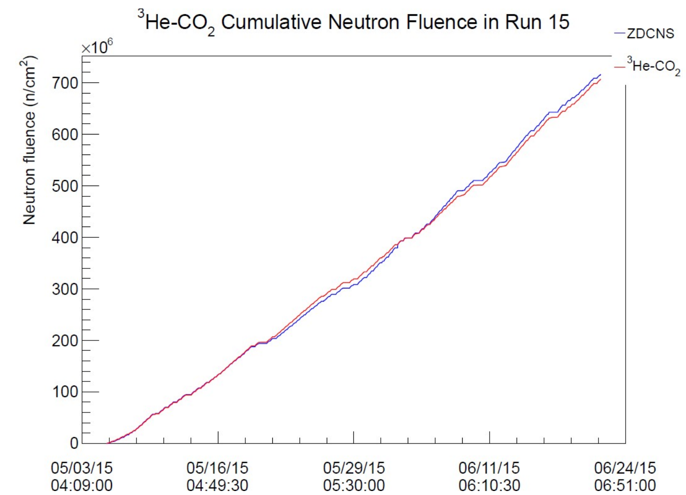
- sector structure designed
  - issues of cabling, cooling and electronics in empty space to be done
  - structural analysis to be done

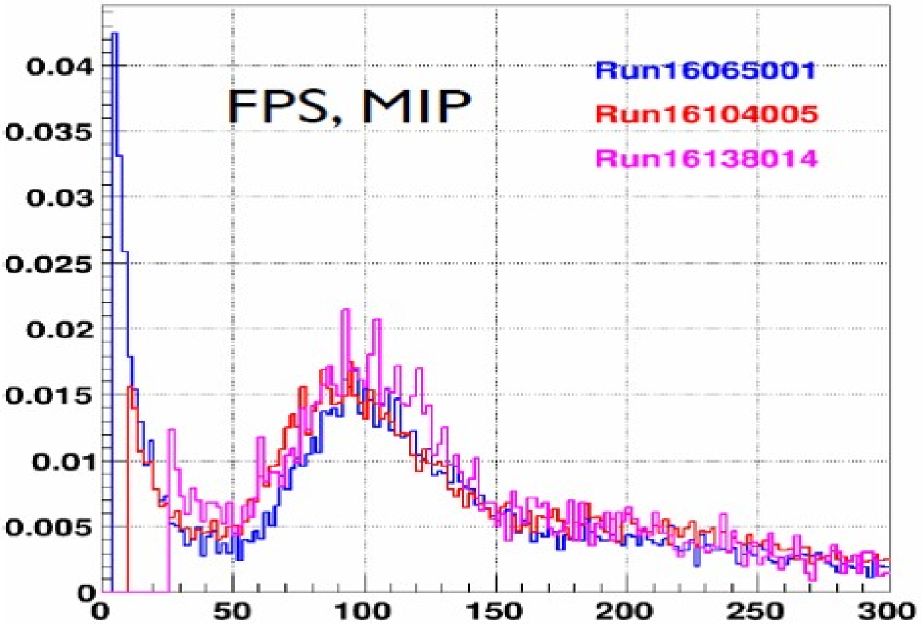


technical status—SiPMs

- SiPMs subject to damage from MeV neutrons
  - neutron fluence ~2×10^{10} n/cm^2/run year
- cooling to 20C reduces radiation damage effects
- measurements at STAR show increased leakage current but stable MIP peak
  - expect leakage current in 3 yrs of sPHENIX will not significantly impact signals of interest; SiPMs best solution for sPHENIX







issues & concerns

- 1D vs 2D modules
  - need to develop 2D production process to mass produce modules
    - v2 prototype targeted to answer this question
  - work underway at BNL, Illinois
- where are the modules to be produced?
  - industry or university
    - both options being pursued, cost/schedule of industry solution not known yet
    - v1 prototype: constructed partially at both Illinois and THP
- SiPMs are a good sensor choice for these calorimeters
- development of monitoring/calibration scheme